MNIST digits classification using CNN

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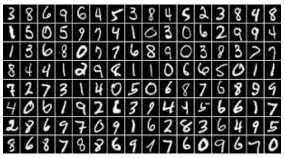


About Dataset

Source

The MNIST database (Modified National Institute of Standards and Technology database) is a large database of handwritten digits that is commonly used for training various image processing systems.

Dataset link: [https://www.kaggle.com/datasets/scolianni/mnistasjpg (https://www.kaggle.com/datasets/scolianni/mnistasjpg)](https://www.kaggle.com/datasets/scolianni/mnistasjpg)

Objective:

To classify images of handwritten digits (0-9) using a CNN model.

Summary

- Data Preparation: Created TRAIN and TEST directories and its sub-folders (classes). Using shutil, moved files in the ratio 80-20 respectively for each class.
- Model Building: Defined a CNN architecture suitable for digit recognition.
- Model Training: Trained the model using the training data.
- Evaluation: Evaluated the model on the test data and plotted the training history.
- Prediction: Made predictions on new images using the trained model.

Importing Libraries

In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns

# pd.set_option('display.max_rows', None)
# pd.set_option('display.max_columns', None)

```

In [2]:
```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense, Dropout
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.optimizers import Adam  # You can try different optimizers


```

Setting the direcory for train & test image data sets

In [3]:
```
source= r'E:\DS journey\Deep Learning Datasets\Digit Image Dataset\Main set'
train_dir = r'E:\DS journey\Deep Learning Datasets\Digit Image Dataset\TRAIN'
test_dir = r'E:\DS journey\Deep Learning Datasets\Digit Image Dataset\TEST'
```

In [4]:
```
import shutil
import os
from sklearn.model_selection import train_test_split
```

In [5]:
```
classes =[i for i in os.listdir(source)]
classes
```

Out[5]:
```
['0', '1', '2', '3', '4', '5', '6', '7', '8', '9']
```

Creating sub-folders for all classes in TRAIN and TEST

In [6]:
```
# # creating directories in TRAIN & TEST, based in Main set
# # This code needs to executed only once


# for i in classes:
#     os.mkdir(os.path.join(train_dir,i))
#     os.mkdir(os.path.join(test_dir,i))
```

Moving files based on 80-20 split

python code for traversing all classes of Source file

```
for i in os.listdir(source):
    j= os.path.join(source,i)
    print(j)
```

```
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\0
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\1
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\2
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\3
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\4
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\5
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\6
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\7
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\8
C:\Users\hp\Python Datasets\Deep Learning\CNN\Digit_Recognizer_CNN\archive (3)\Main set\9
```

In [7]:
```
# for i in os.listdir(source):
#     j= os.path.join(source,i)

#     all_images = os.listdir(j)
#     train_images, test_images =train_test_split(all_images, test_size =0.2, random_state =42)

#     for img in train_images:
#         shutil.move(os.path.join(source,i, img), os.path.join(train_dir,i,img))

#     for img in test_images:
#         shutil.move(os.path.join(source,i, img), os.path.join(test_dir,i,img))
```

Creating ImageDataGenerator objects

In [8]:
```
train_datagen=ImageDataGenerator(rescale=1./255,
                                 rotation_range=40,
                                  width_shift_range =0.2,
                                  height_shift_range =0.2,
                                  shear_range =0.2,
                                  zoom_range =0.2,
                                  horizontal_flip = True,)
test_datagen= ImageDataGenerator(rescale =1/255)
```

Loading TRAIN & TEST images using ImageDataGenerator objects

In [9]:
```
train_generator = train_datagen.flow_from_directory(train_dir,
                                                    target_size= (128,128),
                                                     batch_size =32,
                                                     class_mode ='categorical')
test_generator =test_datagen.flow_from_directory(test_dir,
                                                  target_size =(128,128),
                                                  batch_size =32,
                                                  class_mode ='categorical')
```

```
Found 33595 images belonging to 10 classes.
Found 8405 images belonging to 10 classes.
```

In [10]:
```
d = {"Classes":[i for i in os.listdir(source)],
    "Train_images":[len(os.listdir(os.path.join(train_dir,i))) for i in os.listdir(train_dir)],
    "Test_images":[len(os.listdir(os.path.join(test_dir,i))) for i in os.listdir(test_dir)]
}

df= pd.DataFrame(d)
df
```

Out[10]:

	Classes	Train_images	Test_images
0	0	3305	827
1	1	3747	937
2	2	3341	836
3	3	3480	871
4	4	3257	815
5	5	3036	759
6	6	3309	828
7	7	3520	881
8	8	3250	813
9	9	3350	838

In [11]:
```
# Total No. of images
sum(df.Train_images)+sum(df.Test_images)
```

Out[11]: 42000

In [12]:
```
print("Total Training images: ",sum(df.Train_images),"\nTotal Testing images: ", sum(df.Test_images))
```

```
Total Training images:  33595
Total Testing images:  8405
```

Creating ImageDataGenerator objects

In [13]:
```
train_generator = train_datagen.flow_from_directory(
    train_dir,
    target_size=(128, 128),
    batch_size=32,
    class_mode='categorical')  # Binary classification: cat or dog
```

```
Found 33595 images belonging to 10 classes.
```

In [14]:
```
test_generator = test_datagen.flow_from_directory(
    test_dir,
    target_size=(128,128),
    batch_size=32,
    class_mode='categorical')  # Binary classification: cat or dog
```

```
Found 8405 images belonging to 10 classes.
```

In [15]:
```
num_classes=len(train_generator.class_indices)
train_generator.class_indices
```

Out[15]:
```
{'0': 0,
 '1': 1,
 '2': 2,
 '3': 3,
 '4': 4,
 '5': 5,
 '6': 6,
 '7': 7,
 '8': 8,
 '9': 9}
```

CNN_Model_Architecture

In [16]:

```python
# CNN
model = Sequential()

model.add(Conv2D(32, (3, 3), activation='relu', input_shape=(128, 128, 3)))
model.add(MaxPooling2D((2, 2)))

model.add(Conv2D(64, (3, 3), activation='relu', input_shape=(128, 128, 3)))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(128, (3, 3), activation='relu', input_shape=(128, 128, 3)))
model.add(MaxPooling2D((2, 2)))
model.add(Flatten())

## ANN
model.add(Dense(100, activation='relu'))

model.add(Dense(50, activation='relu')) # hidden

model.add(Dropout(0.5))  # Regularization to prevent overfitting
model.add(Dense(num_classes, activation='softmax'))  # Output layer (cat or dog)
```

```
E:\anaconda3\Lib\site-packages\keras\src\layers\convolutional\base_conv.py:107: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

In [17]:

```python
# Compiling the model
model.compile(
    optimizer='adam',
    loss='categorical_crossentropy',  # Use categorical_crossentropy for multi-class classification
    metrics=['accuracy']
)

# Printing model summary
model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 126, 126, 32)	896
max_pooling2d (MaxPooling2D)	(None, 63, 63, 32)	0
conv2d_1 (Conv2D)	(None, 61, 61, 64)	18,496
max_pooling2d_1 (MaxPooling2D)	(None, 30, 30, 64)	0
conv2d_2 (Conv2D)	(None, 28, 28, 128)	73,856
max_pooling2d_2 (MaxPooling2D)	(None, 14, 14, 128)	0
flatten (Flatten)	(None, 25088)	0
dense (Dense)	(None, 100)	2,508,900
dense_1 (Dense)	(None, 50)	5,050
dropout (Dropout)	(None, 50)	0
dense_2 (Dense)	(None, 10)	510

Total params: 2,607,708 (9.95 MB)

Trainable params: 2,607,708 (9.95 MB)

Non-trainable params: 0 (0.00 B)

Using ModelCheckpoint Callback

In [18]:

```python
# Define ModelCheckpoint callback to save the best weights
from tensorflow.keras.callbacks import ModelCheckpoint
checkpoint = ModelCheckpoint(r'best_model.keras',
                             monitor='val_accuracy', save_best_only=True, mode='max', verbose=1)

# Train the model
history = model.fit(
    train_generator,
    epochs=10,
    validation_data=test_generator,
    callbacks=[checkpoint],
    shuffle = False
)
```

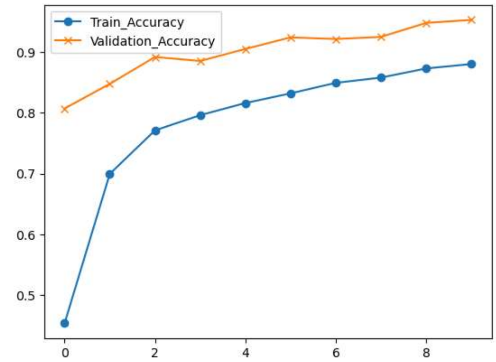
```
Epoch 1/10

E:\anaconda3\Lib\site-packages\keras\src\trainers\data_adapters\py_dataset_adapter.py:121: UserWarning: Your `PyDataset` class should call `super().__init__(**kwargs)` in its constructor. `**kwargs` can include `workers`, `use_multiprocessing`, `max_queue_size`. Do not pass these arguments to `fit()`, as they will be ignored.
  self._warn_if_super_not_called()

1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 695ms/step - accuracy: 0.3104 - loss: 1.8700
Epoch 1: val_accuracy improved from -inf to 0.80690, saving model to best_model.keras
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 813s 772ms/step - accuracy: 0.3106 - loss: 1.8697 - val_accuracy: 0.8069 - val_loss: 0.5895
Epoch 2/10
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 484ms/step - accuracy: 0.6693 - loss: 0.9725
Epoch 2: val_accuracy improved from 0.80690 to 0.84735, saving model to best_model.keras
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 584s 556ms/step - accuracy: 0.6694 - loss: 0.9724 - val_accuracy: 0.8474 - val_loss: 0.3735
Epoch 3/10
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 618ms/step - accuracy: 0.7658 - loss: 0.7009
Epoch 3: val_accuracy improved from 0.84735 to 0.89149, saving model to best_model.keras
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 676s 644ms/step - accuracy: 0.7658 - loss: 0.7009 - val_accuracy: 0.8915 - val_loss: 0.3288
Epoch 4/10
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 426ms/step - accuracy: 0.7883 - loss: 0.6280
Epoch 4: val_accuracy did not improve from 0.89149
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 474s 452ms/step - accuracy: 0.7883 - loss: 0.6279 - val_accuracy: 0.8849 - val_loss: 0.3355
Epoch 5/10
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 429ms/step - accuracy: 0.8118 - loss: 0.5656
Epoch 5: val_accuracy improved from 0.89149 to 0.90470, saving model to best_model.keras
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 478s 455ms/step - accuracy: 0.8118 - loss: 0.5656 - val_accuracy: 0.9047 - val_loss: 0.2776
Epoch 6/10
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 426ms/step - accuracy: 0.8311 - loss: 0.5115
Epoch 6: val_accuracy improved from 0.90470 to 0.92374, saving model to best_model.keras
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 476s 453ms/step - accuracy: 0.8311 - loss: 0.5115 - val_accuracy: 0.9237 - val_loss: 0.2350
Epoch 7/10
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 427ms/step - accuracy: 0.8488 - loss: 0.4705
Epoch 7: val_accuracy did not improve from 0.92374
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 475s 453ms/step - accuracy: 0.8488 - loss: 0.4705 - val_accuracy: 0.9210 - val_loss: 0.2487
Epoch 8/10
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 438ms/step - accuracy: 0.8521 - loss: 0.4652
Epoch 8: val_accuracy improved from 0.92374 to 0.92457, saving model to best_model.keras
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 488s 465ms/step - accuracy: 0.8521 - loss: 0.4652 - val_accuracy: 0.9246 - val_loss: 0.2285
Epoch 9/10
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 428ms/step - accuracy: 0.8689 - loss: 0.4252
Epoch 9: val_accuracy improved from 0.92457 to 0.94753, saving model to best_model.keras
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 477s 454ms/step - accuracy: 0.8689 - loss: 0.4252 - val_accuracy: 0.9475 - val_loss: 0.1799
Epoch 10/10
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 0s 428ms/step - accuracy: 0.8767 - loss: 0.4076
Epoch 10: val_accuracy improved from 0.94753 to 0.95241, saving model to best_model.keras
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 502s 454ms/step - accuracy: 0.8767 - loss: 0.4076 - val_accuracy: 0.9524 - val_loss: 0.1627
```

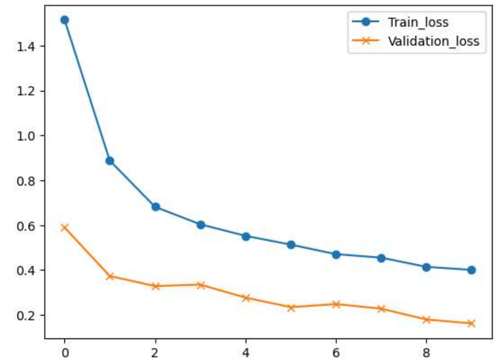
Model-evaluation

In [19]:
```
# Load the best weights
model.load_weights('best_model.keras')

# Evaluate the model
test_loss, test_accuracy = model.evaluate(test_generator)
print(f'Test accuracy: {test_accuracy:.4f}')
print(f'Test loss: {test_loss:.4f}')

# Evaluate the model
train_loss, train_accuracy = model.evaluate(train_generator)
print(f'Train accuracy: {train_accuracy:.4f}')
print(f'Train loss: {train_loss:.4f}')
```

```
263/263 ━━━━━━━━━━━━━━━━━━━━ 28s 106ms/step - accuracy: 0.9516 - loss: 0.1566
Test accuracy: 0.9524
Test loss: 0.1627
1050/1050 ━━━━━━━━━━━━━━━━━━━━ 261s 249ms/step - accuracy: 0.9062 - loss: 0.2954
Train accuracy: 0.9058
Train loss: 0.2925
```

In [20]:
```
import matplotlib.pyplot as plt
plt.plot(history.history['accuracy'], marker ='o' ,label ='Train_Accuracy')
plt.plot(history.history['val_accuracy'], marker ='x',label ='Validation_Accuracy')
plt.legend()
plt.show()

# Similar plot for loss
plt.plot(history.history['loss'], marker ='o',label ='Train_loss')
plt.plot(history.history['val_loss'],marker ='x',label ='Validation_loss')
plt.legend()
plt.show()
```





Make Predictions

In [21]:
```
import os
# Load and preprocess a single image
img_paths= [os.path.join(r'E:\DS journey\Deep Learning Datasets\Digit Image Dataset\testSet\testSet', i) for i in \
                        os.listdir(r'E:\DS journey\Deep Learning Datasets\Digit Image Dataset\testSet\testSet')]

len(img_paths)
```

Out[21]: 28000

In [22]:

```python
img_path_=img_paths[27010:27030]  # enter indices here

for img_path in img_path_:

    # Load and preprocess a single image
    img = tf.keras.preprocessing.image.load_img(img_path, target_size=(128, 128))
    img_array = tf.keras.preprocessing.image.img_to_array(img)
    img_array = np.expand_dims(img_array, axis=0) / 255.0

    # Predict
    prediction = model.predict(img_array)
    predicted_labels = int(np.argmax(prediction, axis=1).reshape(1,1))
    # image plot part
    plt.figure(figsize =(0.5,0.5))
    plt.tick_params(left = False, right = False , labelleft = False ,
                    labelbottom = False, bottom = False)

    plt.imshow(img_array.reshape(128,128,3))
    plt.show()
    print("value of the above image is:",predicted_labels)

```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 163ms/step
```

```
value of the above image is: 2
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 33ms/step
```

```
value of the above image is: 3
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 33ms/step
```

Observations

- The Digit Dataset has 10 classes from 0,1,2...9.
- Firstly created the TRAIN & TEST folders and sub-folders based on classes.
- Using the shutil library copied images from source to respective directories maintaining a 80-20 split.
- Loaded the image data using ImageDataGenrator class object and methods.
- CNN model was created and Results after 10 epochs with 3 Conv layers, 3 max pooling and 3 Dense layers is as follows:
  - Train accuracy: 0.9058- loss: 0.2925
  - Test accuracy: 0.9524- loss: 0.1627